INR-0904/95
October 1995
hep-ph/9510247

BFKL QCD Pomeron in High Energy Hadron Collisions and Inclusive Dijet Production [1]

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Abstract

We calculate inclusive dijet production cross section in high energy hadron collisions within the BFKL resummation formalism for the QCD Pomeron. We take into account the Pomerons which are adjacent to the hadrons. With these adjacent Pomerons we define a new object — the BFKL structure function of hadron — which enables one to calculate the inclusive dijet production for any rapidity intervals. We present predictions for the dijet K-factor and azimuthal angle decorrelation. Estimations for some NLO BFKL corrections are also given.

[1]To appear in *the Proceedings of the Workshop on Particle Theory and Phenomenology*, the International Institute of Theoretical and Applied Physics, Ames, Iowa, May 1995

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At present, much attention is being paid to the perturbative QCD Pomeron obtained by Balitsky, Fadin, Kuraev and Lipatov (BFKL) [1]. One of the reasons is that it relates hard processes ($-t = Q^2 \gg \Lambda^2_{QCD}$) and semi-hard ones ($s \gg -t = Q^2 \gg \Lambda^2_{QCD}$): It sums up leading energy logarithms of perturbative QCD into a singularity in the complex angular momentum plane. Several proposals to find direct manifestations of the BFKL Pomeron are available in the literature, see, e.g., Refs. [2-4], but it is still difficult to get the necessary experimental data.

In this presentation we outline, within the BFKL approach, the inclusive dijet cross section in high energy hadron collisions without any restrictions on untagging jets [5]. Our goal is to push further towards the existing experimental conditions the BFKL Pomeron predictions.

Removing the restriction on tagging jets to be most forward/backward, which was imposed in the previous studies, one should take into account additional contributions to the cross section with jets more rapid than the tagging ones. There are three such contributions: two with a couple of Pomerons (Figs. 1(b),1(c)) and one with three (Fig. 1(d)). We will call the Pomerons developing between colliding hadrons and their descendant jets the adjacent Pomerons and the Pomeron developing between the tagging jets the inner Pomeron. These additional contributions contain extra power of α_S per extra Pomeron but hardly could they be regarded as corrections since they are also proportional to a kinematically dependent factor which one can loosely treat as the number of partons in the hadron moving faster than the descendant tagging jet.

Mueller and Navelet result [3] for contribution to the cross section of Fig. 1(a) could be recast [5] as

$$\frac{x_1 x_2 d\sigma_{\{P\}}}{dx_1 dx_2 d^2k_{1\perp} d^2k_{2\perp}} = \frac{\alpha_S C_A}{k^2_{1\perp}} \frac{\alpha_S C_A}{k^2_{2\perp}} \times$$
$$\sum_n \int d\nu x_1 F_A(x_1, \mu_1^2) \left[\chi_{n,\nu}(k_{1\perp}) e^{y\omega(n,\nu)} \chi^*_{n,\nu}(k_{2\perp})\right] x_2 F_B(x_2, \mu_2^2). \tag{1}$$

where the subscript on $\sigma_{\{P\}}$ labels the contribution to the cross section as a single inner Pomeron; $C_A = 3$ is a color group factor; x_i are the longitudinal momentum fractions of the tagging jets; $k_{i\perp}$ are the transverse momenta; $xF_{A,B}$ are the effective structure functions of colliding hadrons; $y = \ln(x_1 x_2 s / k_{1\perp} k_{2\perp})$ is the relative rapidity of tagging jets; $\chi_{n,\nu}(k_\perp) = \frac{(k^2_\perp)^{-\frac{1}{2}+i\nu} e^{in\phi}}{2\pi}$ are Lipatov's eigenfunctions and $\omega(n,\nu) = \frac{2\alpha_S C_A}{\pi}\left[\psi(1) - Re\,\psi\left(\frac{|n|+1}{2} + i\nu\right)\right]$ are Lipatov's eigenvalues. Here ψ is the logarithmic derivative of Euler Gamma-function.

As we have shown [5], subprocesses of Fig. 1(b)-1(d) with the adjacent Pomerons contribute to the effective structure functions, i.e., one can account for them by just adding some "radiation corrections" to the structure functions of Eq.(1):

$$\begin{aligned} xF_A(x_1, \mu_1^2) &\Rightarrow x\Phi_A(x_1, \mu_1^2, n, \nu, k_{1\perp}) \equiv xF_A(x_1, \mu_1^2) + xD_A(x_1, \mu_1^2, n, \nu, k_{1\perp}), \\ xF_B(x_2, \mu_2^2) &\Rightarrow x\Phi^*_B(x_2, \mu_2^2, n, \nu, k_{2\perp}) \equiv xF_B(x_2, \mu_2^2) + xD^*_B(x_2, \mu_2^2, n, \nu, k_{2\perp}), \end{aligned} \tag{2}$$

where $x\Phi_{A,B}$ are the new structure functions that depend on Lipatov's quantum numbers (n, ν) — we call them BFKL structure functions; the complex conjugation on Φ_B could be understood if one look at rhs of Eq. (1) as a matrix element of a t-channel evolution operator with the relative rapidity, y, as an evolution parameter and F_B as a final state; (n, ν) are then "good quantum numbers" conserved under the evolution—this makes room for (n, ν)-dependence of the corrected structure functions. We note also that the corrected structure functions may depend on the transverse momenta of the tagging jets. An explicit expression for the radiation correction $D_{A,B}$ to the effective hadron structure functions see in Ref. [5].

Eq. (1) with the substitution (2), makes possible to get updated predictions for the K-factor and the azimuthal angle decorrelation of x-symmetric $(x_1 = x_2)$ dijets on an effective relative rapidity $y^* \equiv \ln(x_1 x_2 s/k^2_{\perp min})$ (see Figs. 2,3, where the LO CTEQ3L structure functions [6] have been used).

A look at the plots brings a conclusion that the adjacent Pomerons may play a decisive role in the high energy hadron collisions. We note also that one should not stick anymore to the large dijet relative rapidity region in the BFKL Pomeron manifestations hunting, since, from the one hand, we include the region of the moderate rapidity intervals into our consideration and, from the other hand, the resummation effects are quite pronounced at the moderate rapidity region.

We present also in Figs. 2,3 estimations for NLO BFKL effects using the results of Ref. [7], where conformal NLO contributions to the Lipatov's eigenvalues were calculated. The estimations incorporate the NLO conformal corrections to the Lipatov's eigenvalues (see Fig. 4) and the NLO CTEQ3M structure functions [6].

We should note here that the extraction of data on high-$k_\perp$ jets from the event samples in order to compare them with the BFKL Pomeron predictions should be different from the algorithms directed to a comparison with perturbative QCD predictions for the hard processes. These algorithms, motivated by the strong $k_\perp$-ordering of the hard QCD regime, employ hardest-$k_\perp$ jet selection (see, e.g., Ref. [8]). It is doubtful that one can reconcile these algorithms with the weak $k_\perp$-diffusion and the strong rapidity ordering of the semi-hard QCD regime, described by the BFKL resummation. We also note that our predictions should not be compared with the preliminary data [9] extracted by the most forward/backward jet selection criterion. Obviously, one should include for tagging all the registered pairs of jets (not only the most forward–backward pair) to compare with our predictions. In particular, to make a comparison with Figs. 2,3, one should sum up all the registered x-symmetric dijets $(x_1 = x_2)$ with transverse momenta harder than $k_{\perp min}$.

We thank E.A.Kuraev and L.N.Lipatov for stimulating discussions. We are grateful to A.J.Sommerer, J.P.Vary, and B.-L.Young for their kind hospitality at the IITAP, Ames, Iowa and support. V.T.K. is indebted to S.Ahn, C.L.Kim, T.Lee, A.Petridis, J.Qiu, C.R.Schmidt, S.I.Troyan, and C.P.Yuan for helpful conversations. V.T.K. also thanks the Fermilab Theory Division for hospitality. G.B.P. wishes to thank F.Paccanoni for fruitful discussions and hospitality at the Padova University.

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Figure Captions

Fig. 1: Subprocesses for the dijet production in hadron collision.
Fig. 2: The y^*-dependence of the dijet K-factor.
Fig. 3: The y^*-dependence of the average azimuthal angle cosine between the tagging jets.
Fig. 4: The Lipatov's eigenvalues at $n = 0$.

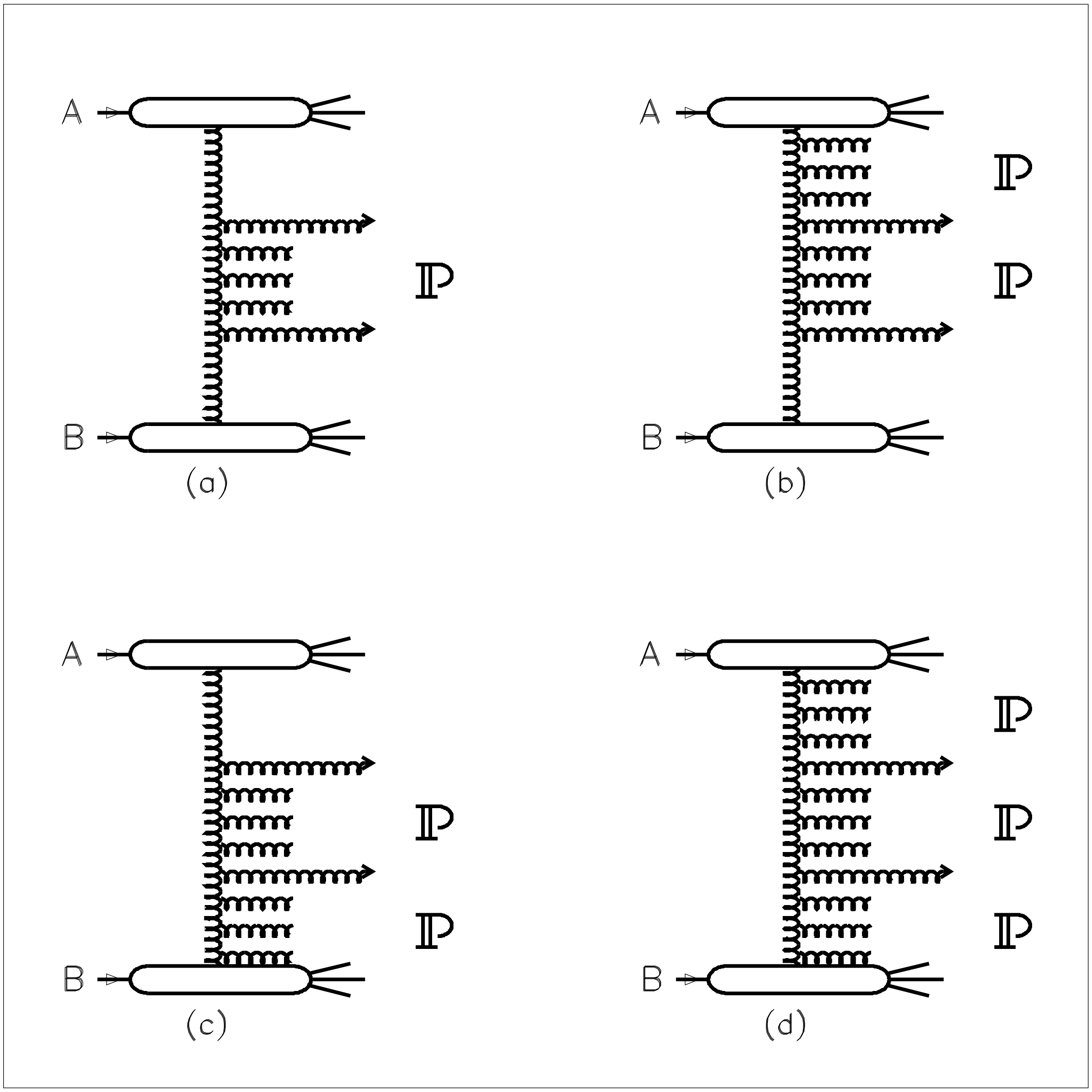


Fig.1

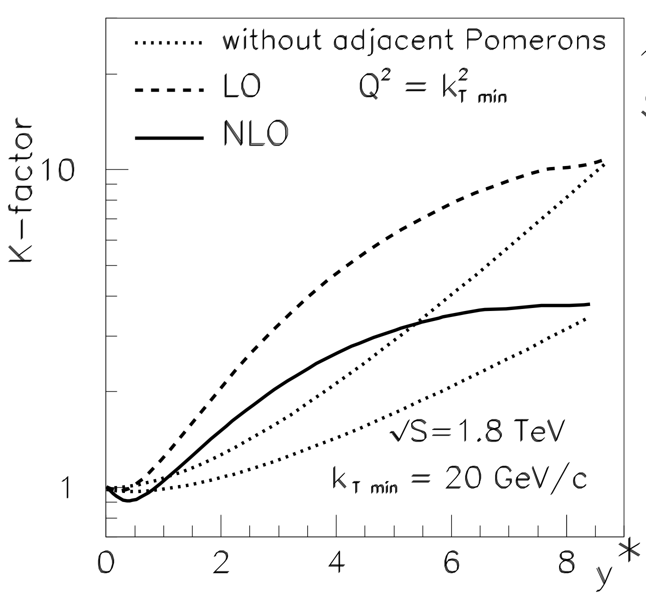


Fig.2

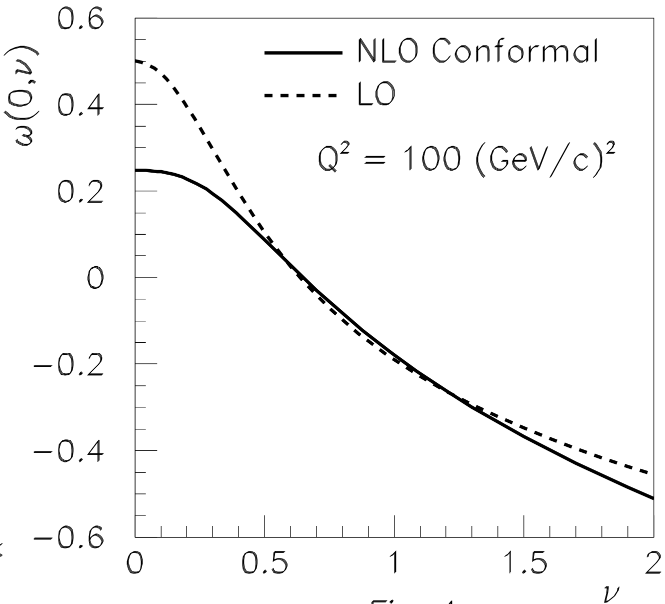
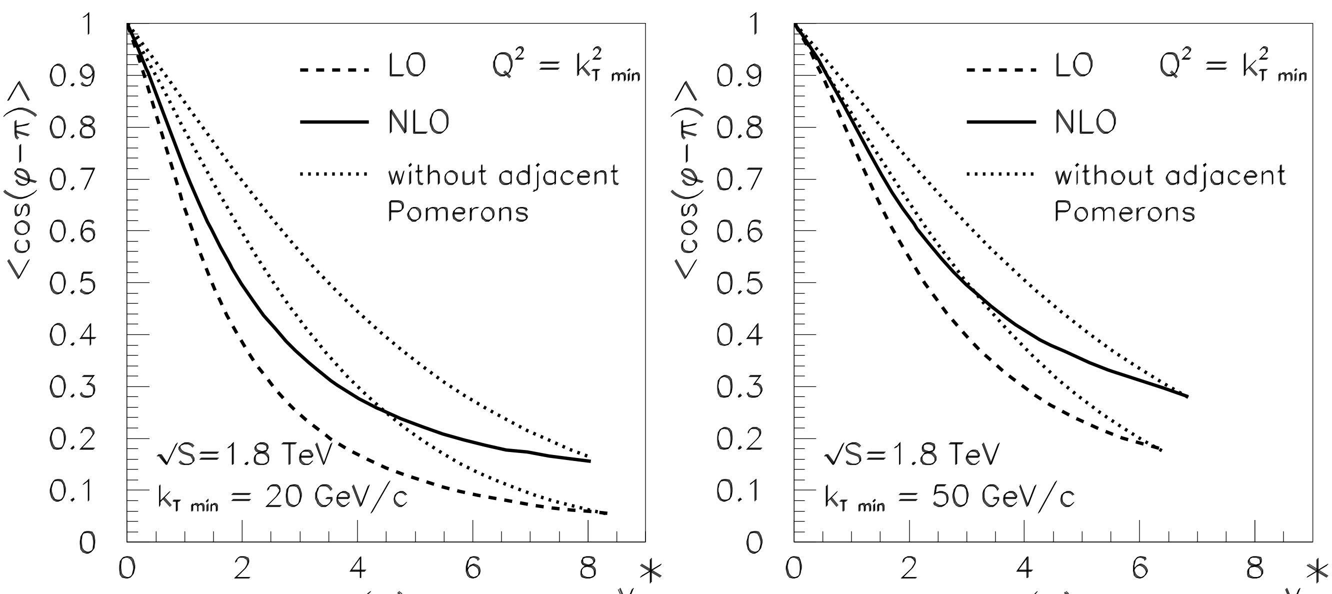


Fig. 4



(a) (b)

Fig. 3

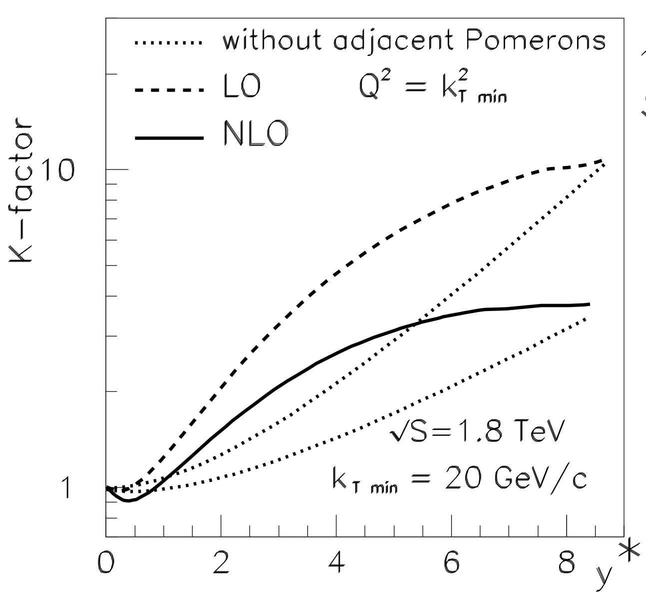


Fig.2

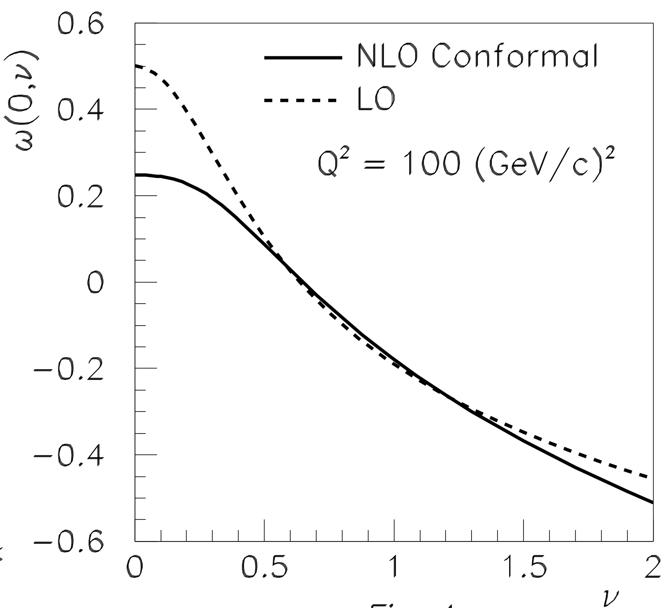


Fig. 4

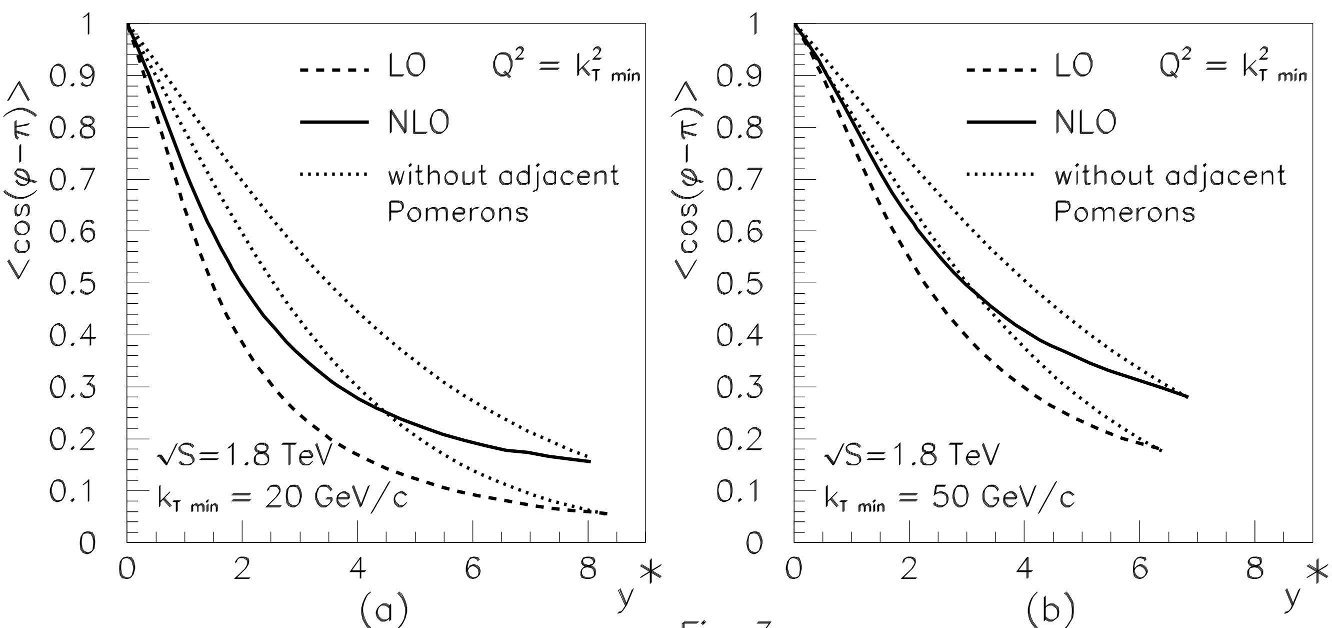


Fig. 3